Long-term monitoring of the glaciers in Wordie Bay, Antarctic Peninsula, using multi-mission SAR time series

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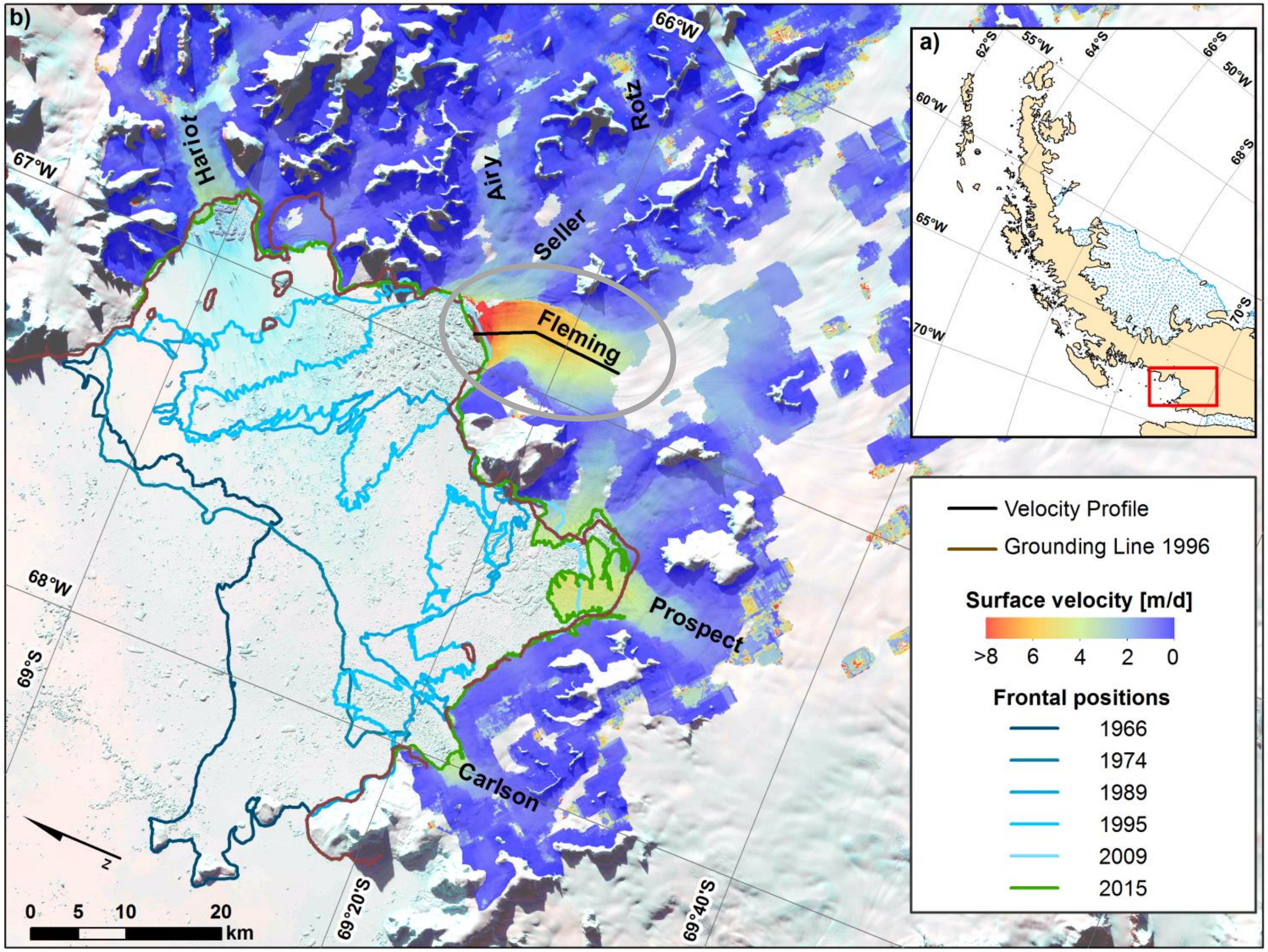
Outline

1. Overview of the Study Area: Wordie Ice Shelf



Surface velocities on 2015/09/03 from Sentinel-1 acquisitions

Background image: Landsat-8 acquisition on 2015/09/16 ©USGS

2. Motivation

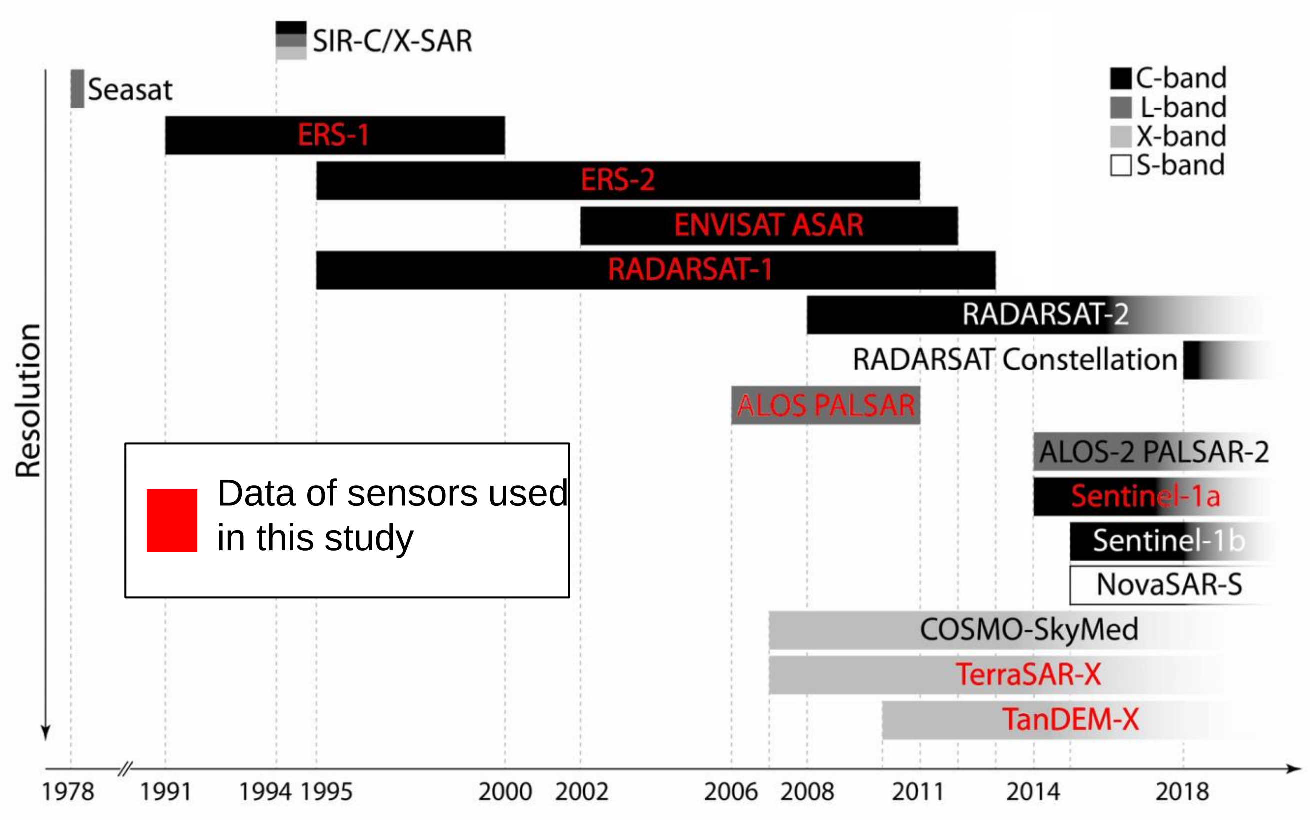
- What we know from other studies (Rignot et al. 2005, Wendt et al. 2010):
  - Acceleration of Fleming Glacier between 1974 and 1996 of about 40 – 50% (50 km upstream of the grounding line in 1996) due to a loss of buttressing
  - Substantial dynamic thinning
- No studies which investigated the long-term adaption process of Fleming Glacier to the loss of the ice shelf

➔ High resolution ice velocity time series 1994 – 2016

➔ Elevation change rates 2004 – 2014

➔ Recent grounding line position

3.Velocity Measurements
a) Data & Methods

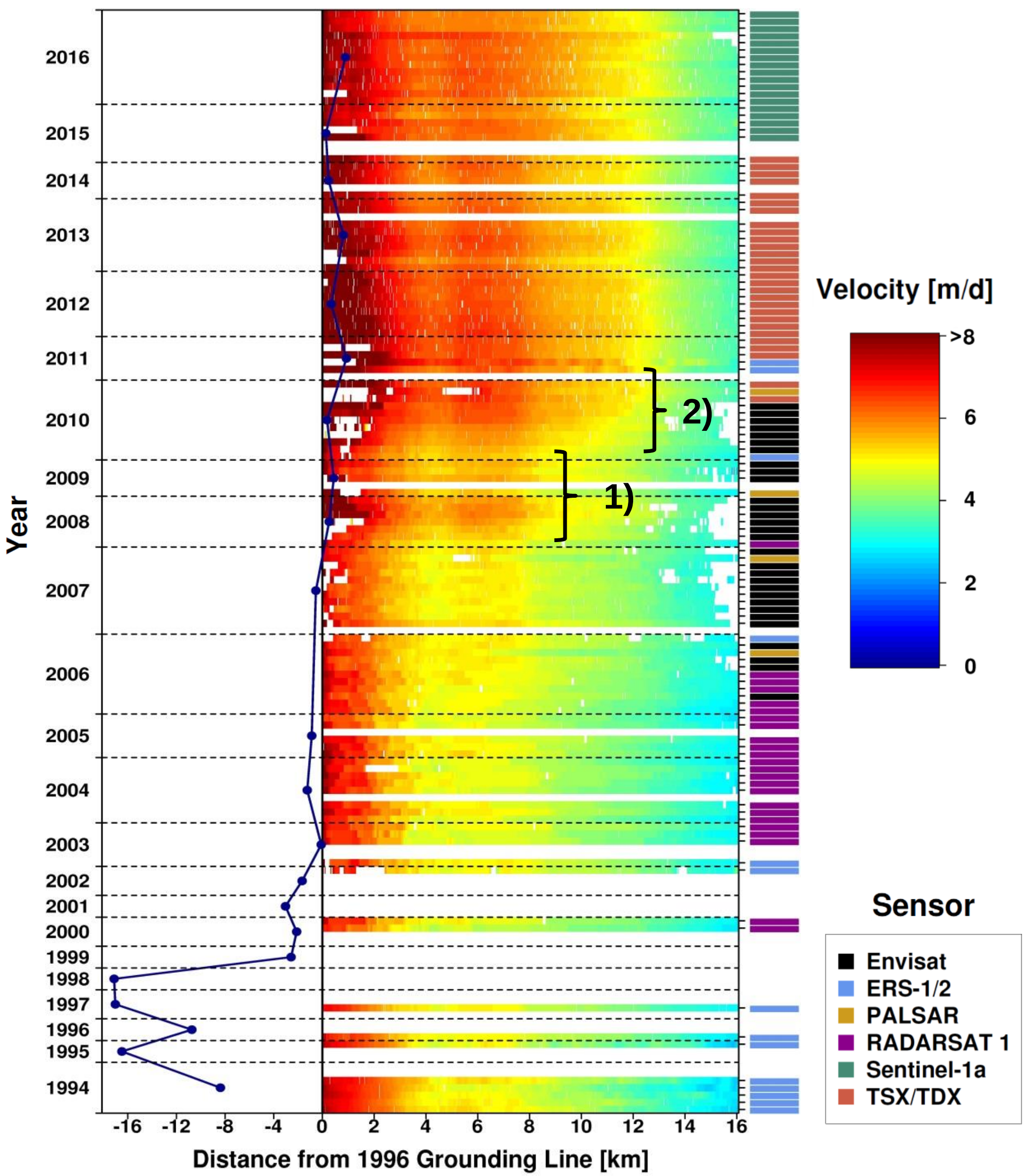


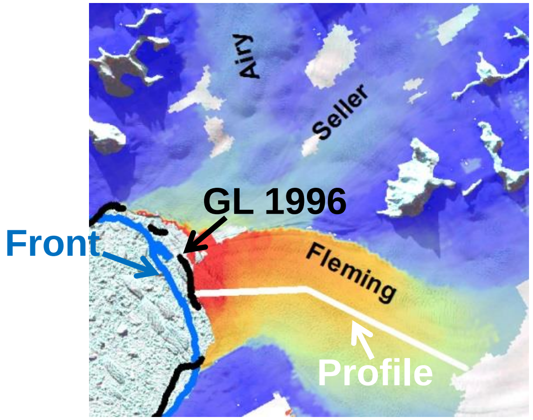
(modified after Pope et al. 2014)

- Glacier surface velocities from SAR-feature tracking
- > 400 scenes acquired by 8 SAR-sensors were processed
- Time coverage: 1994 – 2016

3.Velocity Measurements

b) Results





- Stable velocities from 1994 to 2007

1) April 2008:

- sudden acceleration and inland propagation of high velocities

2) March 2010 – early 2011:

- Further gradual inland propagation of acceleration

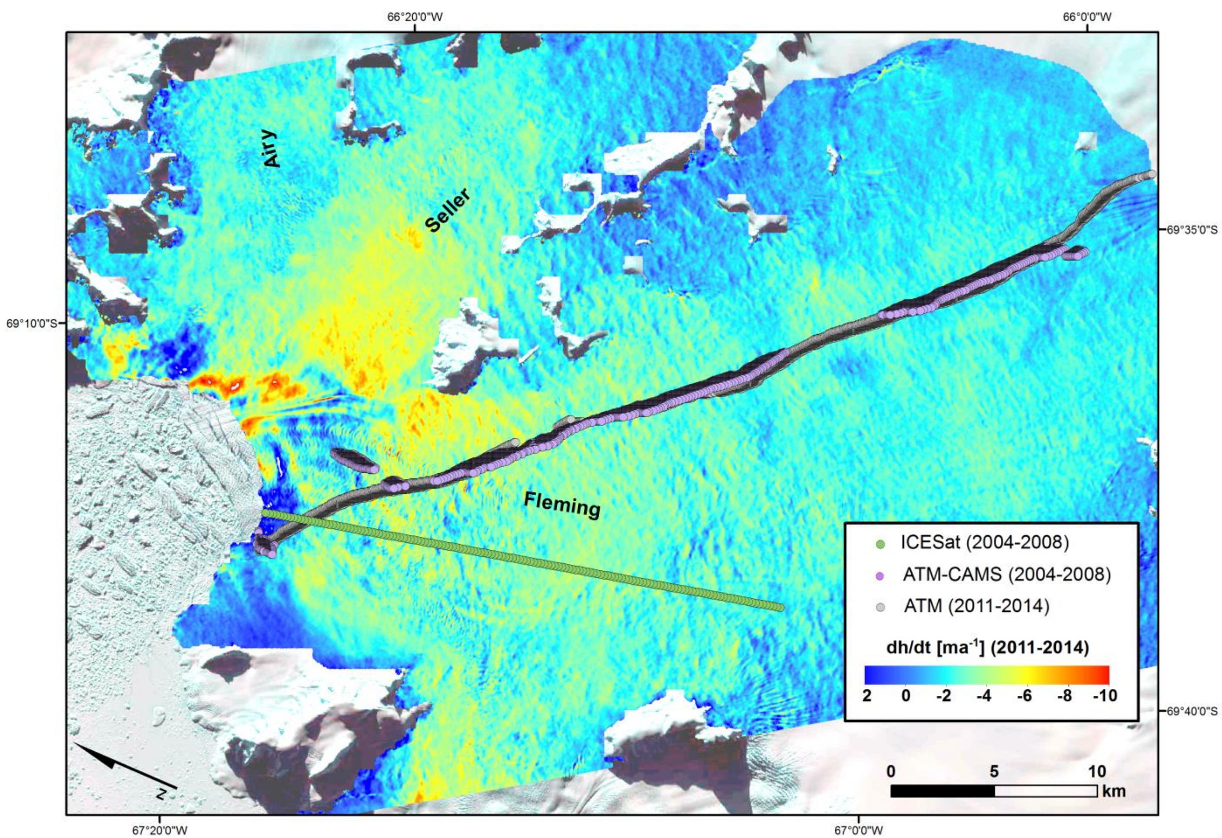
- Median acceleration 2007 – 2013 ≈1,2 md^{-1}
- No major ice break up events prior to acceleration
- In 2008: front first time behind GL of 1996
- Hypothesis: acceleration due to a sudden and a gradual stage of grounding line retreat

4. Elevation Change
a) Data & Methods

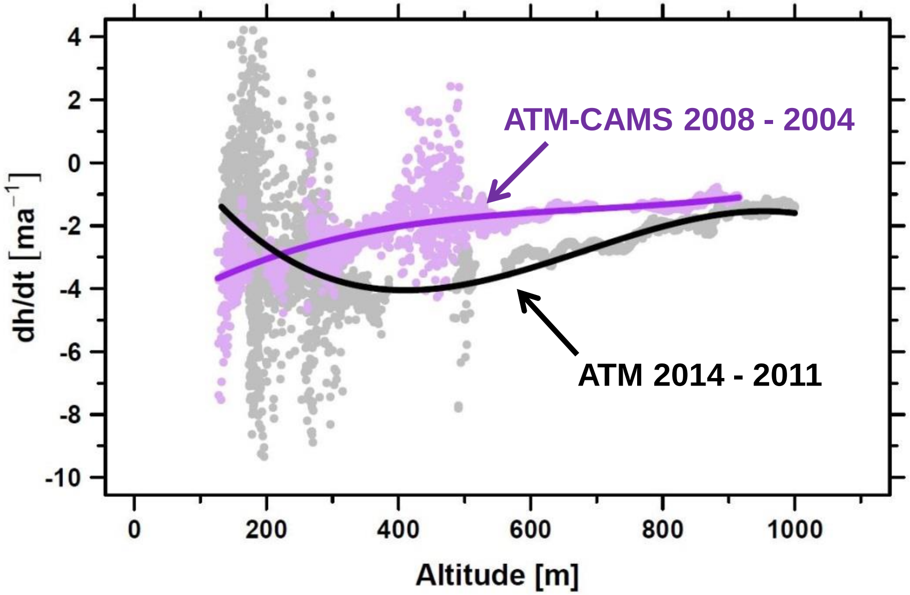
Mission	Sensor	Type	Dates of Acquisition
Pre-IceBridge	ATM	Airb. Laser	2004-11-18
CECS/FACH	CAMS	Airb. Laser	2008-12-07
ICESat	GLAS	Sat. Laser	2004-05-18 2008-10-04
TSX/TDX	X-Band SAR	Interfer. DEM	2011-11-21 2014-11-03
Operation IceBridge	ATM	Airb. Laser	2011-11-17 2014-11-10

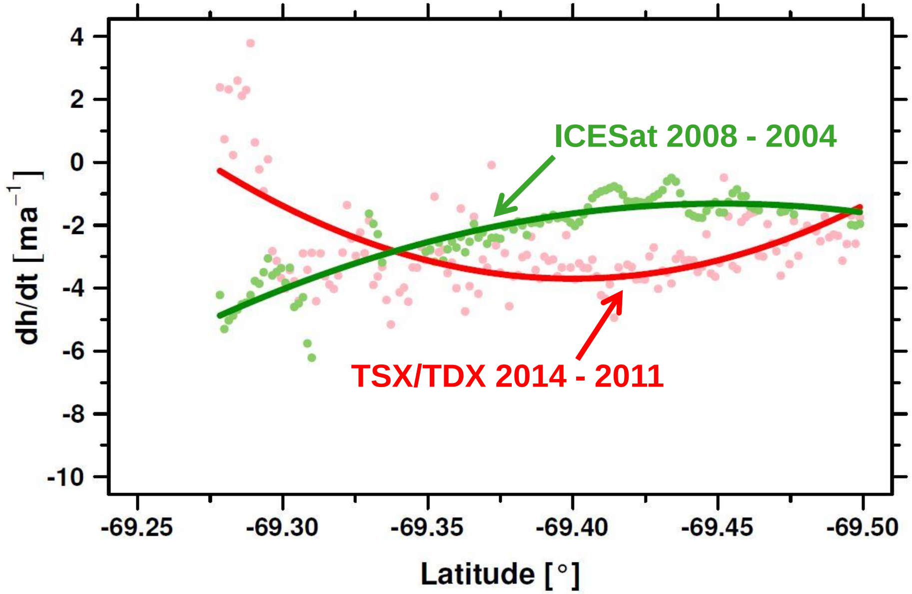
Before acceleration (2004-2008)

After acceleration (2011 – 2014)



4. Elevation Change
b) Results





Before acceleration (2004 – 2008)

- Dynamic thinning in response to former ice shelf loss
- Highest ice thinning rates of about -4 ma^{-1} - -5 ma^{-1} downstream, close to the 1996 GL
- Pronounced basal melt at the GL ➔ trigger of recent GL retreat

After acceleration (2011 – 2014)

- 60 - 70% increase of median dynamic thinning rates
- Highest ice thinning rates of about -4 ma^{-1} migrated upstream (together with the GL)
- Tendency to lower ice thinning rates towards the front ➔ ice floatation

5. Grounding Line Reconstruction

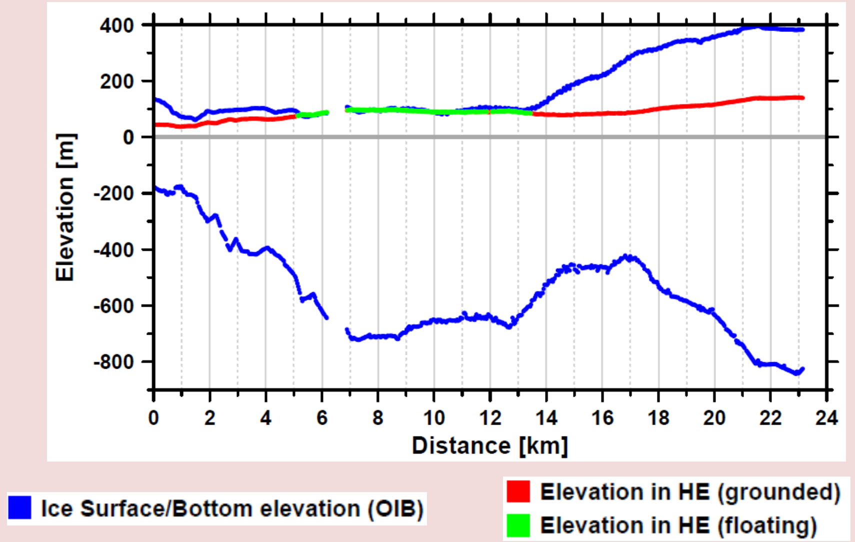
a) Data & Methods

Ice thinning rate patterns on TSX/TDX dh/dt map

➕

IceBridge laser altimeter ice elevations VS potential ice elevations in hydrostatic equilibrium from **IceBridge ice thickness data**

➔**hydrostatic height anomalies**

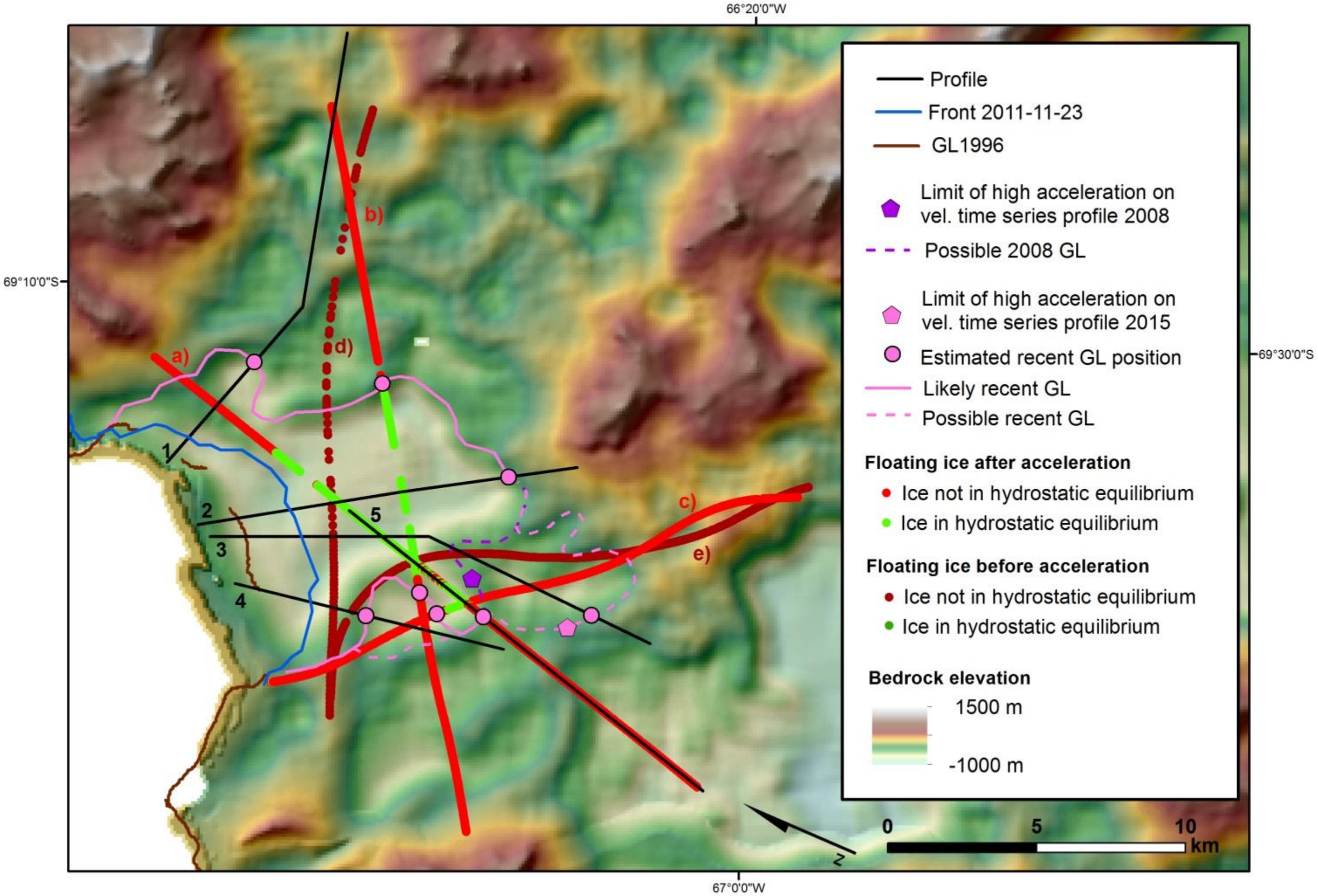


➕ **Acceleration patterns** along velocity profiles across the study area

➕ **Modelled bedrock topography** (Huss & Farinotti 2014)

Estimation of recent grounding line position

5. Grounding Line Reconstruction
b) Results



- OIB data: the glacier tongue was not floating before the acceleration, but after the acceleration
- Bedrock data: Limits of floatation follow the ridges which confine the through-shaped glacier bed ➔ ridges act as new pinning points, through has promoted the rapid GL retreat in 2008
- GL came to a stop at a first ridge in 2008 and then gradually retreated over a second trough to the recent position
- GL retreated by 10 – 13 km between 2008 and today

Conclusion

- Until 2008 Fleming Glacier was pinned at the GL of 1996

- **Continuous dynamic thinning** related to the loss of the former ice shelf and **basal melt** at the grounding line, in combination with a **trough-shaped bed topography**, have caused a big part of the **glacier tongue to suddenly go afloat in April 2008**

- The GL further **gradually retreated between March 2010 and May 2011**, and is now located 10-13 km upstream of its old position

- The GL retreat led to an **inland propagation of acceleration and dynamic thinning**. The median acceleration was ≈1.2 md^{-1} between 2007 and 2013 and the median increase in ice thinning was 60 – 70%

- The onset of the GL retreat corresponds with the findings of Wouters et al. (2015) who report a **near-simultaneous acceleration in dynamic ice mass loss all across the western Antarctic Peninsula south of -70° between 2008 and 2009**
  ➔ enhanced oceanic melt at the bottom of ice shelfs and grounding lines due to **intruding warm CDW**

- Today the dynamics of Fleming Glacier seem to be **primarily controlled by recent oceanic forcing** rather than the former disintegration of the ice shelf

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Thank you for your attention!

Paper on the presented results is under preparation!

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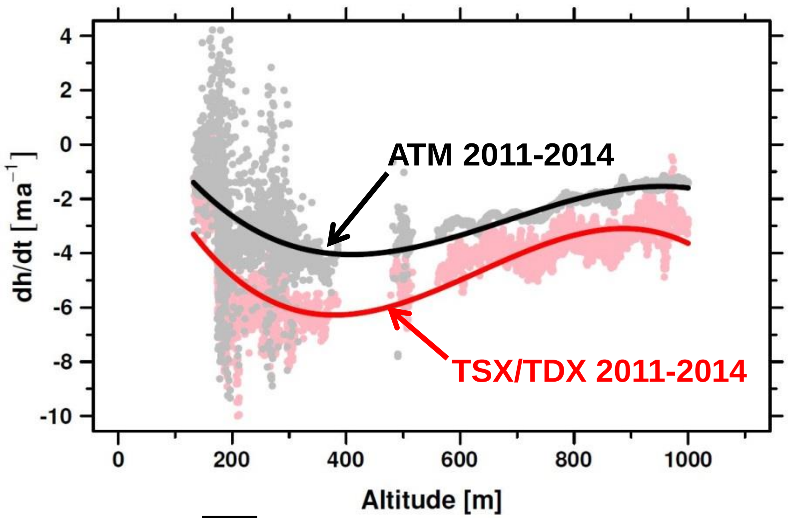
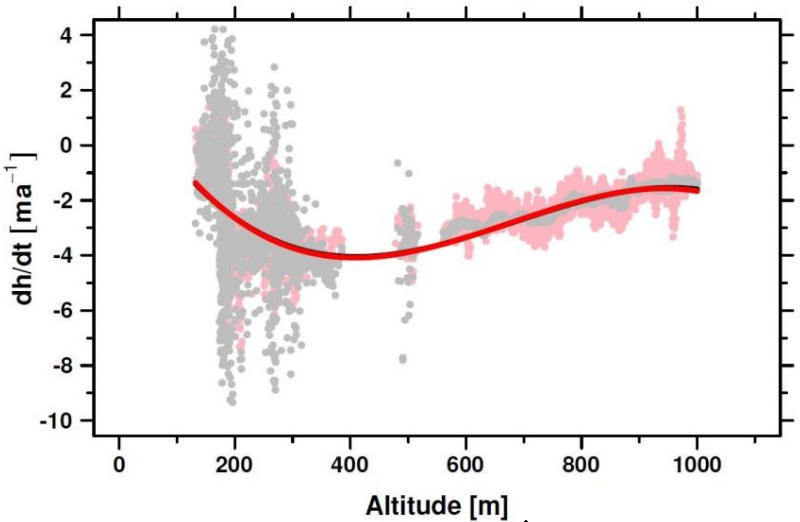
4. Elevation Change
a) Data & Methods

Penetration depth bias correction of TDX differential DEM

After vertical referencing of interferometric TDX-DEMs on sea level:



After application of the model to the entire glacier area:



Penetration depth correction model